Determining Toxicity of "Naturally" Occurring Contaminants Under the Washington State Department of Ecology's Sediment Management Standards

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There is significant confusion about the terms "Natural" versus "Anthropogenic" sediment contamination and how to evaluate these seemingly different types of contamination. The intent of this paper is to clarify the Washington State Department of Ecology's perspective regarding biological assessment of "Natural" versus "Anthropogenic" sources of contamination. It is also the intent of this paper to help to describe how the occurrence of natural contaminants at recognized reference stations should be interpreted for the best protection of human health and the environment through implementation of the Washington State's Sediment Management Standards, Chapter 173-204 WAC.

APPROACHES TO TOXICITY TEST EXPOSURES

The origins of the sediment toxicity evaluations described in the Dredged Material Management Program (DMMP) guidelines and the SMS program standards are rooted in the Puget Sound Protocols and Guidelines (1986, 1991, 1995). These protocols were developed with the knowledge that the sediments would to be dredged for navigation and commerce, and most would be disposed of at deep, open-water disposal sites. Thus, the protocols were intended to represent the act of disposal, e.g., allowing for some reduction of semi-volatile compounds during settling. Test conditions simulate exposure conditions similar to those during the disposal process and/or found at the disposal sites. For example, sediment samples are mixed and allowed to settle in test chambers prior to the introduction of the test organisms.

From the perspective of the SMS program, the above approach is problematic for at least two reasons. The first is that the preferred management alternative for source control or cleanup sites is not always to dredge the sediments. The second is that the above-referenced test protocols establish conditions that do not represent the ***in situ*** sediment conditions that need to be accurately characterized at SMS cleanup sites. Sediment chemical analyses and toxicity tests that are conducted to characterize cleanup sites (MTCA/SMS) are designed to determine the horizontal and vertical extent (spatial boundaries) of ***in situ*** sediment contamination and/or toxicity. Sampling and analysis is focused primarily on the biologically active zone of these sediments (surface; approximately 0-10 cm) where contaminants pose the greatest risk to human health and the environment. Additional evaluation of the underlying sediment is often necessary to determine human health and ecological risks that may remain after any dredging occurs.

"NATURAL" VERSUS "ANTHROPOGENIC" CONTAMINANTS

Perhaps one of the most misunderstood concepts regarding contamination is due to the misinterpretation of term "natural". A "natural" contaminant is one that can occur without human introduction, whereas "anthropogenic" contaminants are produced through human activity. However, "natural" contaminants can also have anthropogenic origins. It is also not the mere presence of the contaminant that makes its toxic, but its concentration. Concentrations of "natural" contaminants can easily be augmented by anthropogenic activities, creating a circumstance where the resulting concentration of the compound exceeds its toxicity threshold and causes significant ecological harm.

Most benthic organisms have evolved either physiologically or behaviorally to the normal range of concentrations of naturally occurring compounds. This results, in part, to their differing tolerance and divergent habitat preferences. Relatively short exposures to "natural" contaminants at the higher end of the normal range can be tolerated with little affect at the population level beyond natural seasonal fluctuations. When the levels of these "naturally" occurring compounds or conditions exceed the normal "background" range, however, threshold conditions may be reached and significant toxicity may be measured. When more than one "natural" or "anthropogenic" compound or condition exists at the site, this can further increase the stress on the biota and even greater biological impacts may occur. These impacts may be in the form of acute effects, e.g., mortality, or chronic endpoints such as reduced reproductive success or changes in certain benthic community measures.

AMMONIA AS A "NATURAL" CONTAMINANT

One of the major "naturally" occurring contaminants that has received significant attention over the years with regard to sediment evaluation is ammonia. Ammonia is a common byproduct of bacterial degradation of nitrogen-rich compounds found in the sediments. The source of the nitrogen, however, can be from natural sources such as organic-rich plant and animal materials, or from anthropogenic compounds such as synthetic amines and amides. Often times, even natural sources of nitrogen-containing plant and animal materials are significantly augmented by anthropogenic activities. These include processing and handling of plant material for manufacturing of paper and wood products and food processing activities (e.g. fish, shellfish or meat rendering). Other inputs of high organic loads that can be contributors of nitrogen are human sewage, solid waste disposal, incineration, and run-off due to erosion-enhancing activities such as road construction, mining and logging near steam beds. Agricultural and residential application of natural and chemical fertilizers is also a contributor to nitrogen-loading of sediments. In areas where intense livestock production exists, highly organic animal waste can also increase nitrogen concentrations. All of these activities augment nitrogen loading in sediments. Therefore, ***in situ*** sediment evaluations must be performed with careful consideration to ammonia and many other compounds and conditions (sulfides, heavy metals, DO depression, temperature modifications) and compared with reference sediments possessing non-anthropogenically-influenced levels or conditions. Those sites that experience enhanced concentrations of nitrogen-containing compounds and/or possess conditions that provide or promote toxicity-enhancing ammonia and/or nitrogen-

containing, ammonia-producing toxicity are considered potentially deleterious under the Sediment Management Standards when compared to background reference conditions. Those parties responsible for direct or indirect augmentation of "natural" toxic compounds can be considered responsible for violations of the Sediment Management Standards.

AMMONIA IN REFERENCE SEDIMENTS

The Sediment Management Standards require reference sediment comparisons to the sediments at sites being evaluated for potential biological exceedances. The purpose of reference stations is to reflect the natural condition of the sediments in the absence of anthropogenic influences. These anthropogenic influences include any compound or condition that would have the potential to adversely affect the natural conditions of the benthic environment, or that has the potential to adversely affect ecosystem components that may affect higher trophic levels, including man.

The Department of Ecology and the U.S. Environmental Protection Agency identified, evaluated and documented several suitable sediment reference sites in Puget Sound for use in the State of Washington (PSEP, 1991). Any ammonia present at test sites that causes toxicity either solely or in combination with other contaminants is considered to be at least partially responsible for the stress that would cause toxicity above that observed in the sediments tested at the matched reference stations. Because of the requirement for reference station comparisons, purging or other manipulation of surface sediments to remove ammonia from test sites is unwarranted for evaluation of ***in situ*** sediment toxicity for SMS purposes. Evaluation of purged or manipulated sediment samples is only appropriate for potentially determining the ultimate cleanup alternative (capping, dredging, etc.)

Because there has been no comprehensive evaluation of potential freshwater reference sediment sites, these sites are currently approved on a case-by-case basis due to the heterogeneity of freshwater sediments and site conditions. A similar rationale for assessing potentially contaminated sites containing "naturally-occurring" compounds that may affect toxicity should also be performed for freshwater sediment evaluations.

SUMMARY

Evaluation of Sediment toxicity for compliance with Sediment Management Standards (SMS) requires the use of reference sediments for comparisons. It is assumed that these reference sediments represent ***in situ*** sediment conditions unaltered by anthropogenic activities. These reference sediments contain naturally occurring compounds which may cause toxicity if found in concentrations above normal "background" reference sediment conditions. Augmentation of these compounds by anthropogenic sources may exceed the natural tolerance range of the benthic community or bioassay test organisms and cause significant toxic effects. Those parties responsible for direct or indirect augmentation of "natural" toxic compounds can be considered responsible for violations of the Sediment Management Standards.

REFERENCES

PSEP. 1986. (revised 1991, 1995). Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediment. In: Puget Sound Protocols and Guidelines, Puget Sound Estuary Program. Final Report by PTI Environmental Services for US Environmental Protection Agency, Region 10, Seattle, WA.

PTI. 1991a. Puget Sound Reference Areas Survey Quality Assurance Reports for chemical analysis. Prepared for US Environmental Protection Agency, Region 10, Seattle, WA., and Washington State Department of Ecology, Olympia, WA.

PTI 1991b. Puget Sound Reference Areas Survey Quality Assurance Reports for Bioassay Analysis. Prepared for US Environmental Protection Agency, Region 10, Seattle, WA., and Washington State Department of Ecology, Olympia, WA.

PTI. 1991c. Reference Area Performance Standards for Puget Sound. Puget Sound Estuary Program: Final Report for US Environmental Protection Agency, Region 10, Seattle, WA, and Washington State Department of Ecology, Olympia, WA. (EPA 910/9-91-041).